

PATENT APPLICATION

TITLE OF THE INVENTION

"N-Well and Other Implanted Temperature Sense Resistors in Inkjet  
Print Head Chips"

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CROSS-REFERENCE TO RELATED APPLICATIONS

10 Not applicable

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR  
DEVELOPMENT

Not applicable

REFERENCE TO A "MICROFICHE APPENDIX"

15 Not applicable

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to printers. More particularly, the present  
invention relates to ink jet printers.

20 2. General Background of the Invention

Inkjet print heads require well-controlled substrate temperature to maintain a  
consistent ink viscosity and jetting performance. Previous designs include a  
temperature sense resistor (TSR) integrated into the heater chip to monitor the  
substrate temperature. The chip also has designated resistor elements to heat the  
25 substrate as necessary. The resistor elements may have dedicated power FETs to  
control the substrate heater resistors, as in Lexmark's U.S. Patent No. 6,102,515  
(incorporated herein by reference). Some designs may use the inkjet resistors  
themselves for substrate heating, if the on-time is less than the bubble nucleation  
threshold, as practiced by Hewlett-Packard. The printer control unit periodically  
30 monitors the temperature sense resistor to determine the substrate temperature. Then  
the control unit turns the substrate heaters on and off, accordingly, to maintain the  
proper substrate temperature for optimum jetting performance.

The temperature sense resistor value follows the equations:

$$R_T = R_{\text{ambient}} * (1 + (\alpha * (T - T_{\text{ambient}})))$$

$$R_{\text{ambient}} = R_{S \text{ ambient}} * (L/W)$$

where  $R$  = resistance of the TSR

$\alpha$  = temperature coefficient of resistivity, ( $\Omega/^\circ\text{C}$ ),

5  $T$  = temperature, ( $^\circ\text{C}$ ), and

$R_S$  = sheet resistance, ( $\Omega/\square$ ).

$L$  = length of the TSR material, ( $\mu\text{m}$ )

$W$  = width of the TSR material, ( $\mu\text{m}$ )

Based on this knowledge, the TSR is selected to have a large positive temperature  
 10 coefficient ( $\alpha$ ) and a large resistance ( $R$ ). In the past, the resistor material has  
 typically been chosen to be a metal (AlCu). While metal may have a relatively large  
 positive temperature coefficient, its TSR design is limited by the ability to route  
 enough metal around the chip to get a high enough resistance for easy temperature  
 change detection (see metal resistor 20 in inkjet print head chip 220 in Figure 1).

15 Typical TSR resistances have been 500-1000 ohms. A 500- $\Omega$  TSR, for example, will  
 have a resistance change of approximately 2  $\Omega/^\circ\text{C}$ . A 1000- $\Omega$  TSR, for example, will  
 have a resistance change of approximately 3.5  $\Omega/^\circ\text{C}$ . Metal TSRs are also limited by  
 the wide tolerance range that can occur. The only way to increase the resistance of a  
 metal TSR is to make the trace longer or the width smaller. Making the TSR longer,  
 20 takes up silicon area. Making the TSR width smaller, widens the tolerance band, due  
 to process variations in width. For example, a TSR 2  $\mu\text{m}$  (2 microns) wide, with 0.1  
 $\mu\text{m}$  over-etch on each side will be 1.8  $\mu\text{m}$  wide, a loss of 10% of drawn width. A  
 TSR 20  $\mu\text{m}$  wide, with 0.1  $\mu\text{m}$  over-etch on each side will be 18.8  $\mu\text{m}$  wide, of loss of  
 1% of drawn width. These are some of the issues currently involved with metal TSR  
 25 designs.

The following U.S. Patents, and all patents mentioned herein, are incorporated  
 herein by reference:

U.S. Patent Nos.: 6,450,622; 6,443,558; 6,441,680; 6,382,758; 6,336,713; 6,171,880;  
 6,102,515; 5,300,968; 5,136,305.

30 U.S. Patent No. 6,336,713 discloses a thermal inkjet printhead which uses  
 metal silicon nitride resistors as heaters. This patent mentions that resistors having  
 high bulk resistivity are desirable for use in thermal inkjet printing units, and that the  
 resistors disclosed therein have high bulk resistivity (see column 8, lines 29).

U.S. Patent No. 6,443,558 discloses an inkjet printhead having a thermal bend actuator with a separate titanium nitride heater element. It includes N-well transistors (see column 15).

U.S. Patent No. 6,171,880 discloses a meandering polysilicon heater mounted  
5 on an IC CMOS chip. See column 4, lines 12-18 and 34-41, and column 5, lines 7-36 (fabricated in a CMOS N-well operation).

U.S. Patent No. 6,382,758 discloses an inkjet printhead having TSRs 14 (see column 3, lines 1-5).

U.S. Patent No. 6,450,622 discloses a print head with a semiconductor  
10 substrate that has an N-well layer, but uses TaAl resistors (see column 3, lines 6-7 and 44-46).

U.S. Patent No. 5,136,305 discloses controlling heat to ink reservoirs for inkjet printheads using temperature sensitive resistors (see column 4, lines 30-38).

U.S. Patent No. 5,300,968 discloses a lightly n-doped resistor or a heavily  
15 n+doped polysilicon resistor (both of which have high sheet resistance and high temperature coefficient of resistance) in a temperature compensating circuit in an inkjet printhead (see column 5, line 65 through column 6, line 30).

U.S. Patent No. 6,441,680 discloses a CMOS reference voltage generator using p-type and n-type CMOS transistors. It discusses temperature dependence of  
20 these transistors (see, for example, column 4, lines 8-20).

#### BRIEF SUMMARY OF THE INVENTION

The present invention focuses on the temperature sensitive resistor (TSR) in inkjet print heads. More specifically, the present invention comprises TSRs made of implants (such as of N-well material) in inkjet print heads, inkjet print heads including  
25 these TSRs, and inkjet printers including these inkjet print heads.

The present invention includes an inkjet print head chip having MOS logic blocks, resistor elements to heat the chip, and a controller of the resistor elements, and temperature sense resistors implanted in the chip, the temperature sense resistors being operatively connected to the controller of the resistor elements to enable the  
30 controller to monitor the chip temperature to control the resistor elements to heat the chip.

The present invention also includes a method of controlling the temperature of an inkjet print head chip having MOS logic blocks, comprising providing the print

head chip with at least one substrate heater to heat the chip, providing the print head chip with a controller of the substrate heater, implanting temperature sense resistors in the chip, operatively connecting the temperature sense resistors to the controller of the substrate heater to enable the controller to monitor the chip temperature to control the substrate heater to heat the chip, and using the controller to control the substrate heater to heat the chip.

The temperature sense resistors preferably have a sheet resistance of at least  $20 \Omega/\square$  and a temperature coefficient of resistivity of at least  $0.0010 \Omega/\square/^\circ\text{C}$ . More preferably, the temperature sense resistors have a sheet resistance of at least  $75 \Omega/\square$  and a temperature coefficient of resistivity of at least  $0.0020 \Omega/\square/^\circ\text{C}$ . Even more preferably, the temperature sense resistors have a sheet resistance of at least  $500 \Omega/\square$  and a temperature coefficient of resistivity of at least  $0.0030 \Omega/\square/^\circ\text{C}$ . Most preferably, the temperature sense resistors have a sheet resistance of at least  $1000 \Omega/\square$  and a temperature coefficient of resistivity of at least  $0.0040 \Omega/\square/^\circ\text{C}$ .

The temperature sense resistors preferably comprise N-Well material, but could also comprise NSD material, LDD material, or PSD material, for example. An inkjet print head chip can include, for example, 1 - 1000 temperature sense resistors of the present invention.

Typically, each temperature sense resistor can be  $0.05 - 5000 \mu\text{m}$  wide by  $0.01 - 400,000 \mu\text{m}$  long by  $0.05 - 4 \mu\text{m}$  thick. Preferably, each temperature sense resistor is  $1 - 2000 \mu\text{m}$  wide by  $1 - 200,000 \mu\text{m}$  long by  $0.1 - 3 \mu\text{m}$  thick. More preferably, each temperature sense resistor is  $2 - 1000 \mu\text{m}$  wide by  $2 - 100,000 \mu\text{m}$  long by  $0.2 - 2 \mu\text{m}$  thick.

In the present invention, the MOS logic blocks are preferably CMOS logic blocks.

The novel TSRs of the present invention can be used in various types of ink jet printers (such as Lexmark® Model Z51, Lexmark® Model Z31, and Lexmark® Model Z11, Lexmark® Photo Jetprinter 5770, or Kodak® PPM200).

#### BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

For a further understanding of the nature, objects, and advantages of the present invention, reference should be had to the following detailed description, read in conjunction with the following drawings, wherein like reference numerals denote like elements and wherein:

Figure 1 is a schematic view (not to scale) of a prior art metal TSR design;

Figure 2 is a schematic view (not to scale) of a preferred embodiment of the TSR of the present invention on an inkjet print head chip of the present invention;

Figure 3 shows a preferred embodiment of an inkjet print head of the present invention including an inkjet print head chip of the present invention; and

Figure 4 shows a preferred embodiment of the inkjet printer of the present invention.

#### DETAILED DESCRIPTION OF THE INVENTION

The present invention comprises TSRs 10 (Figure 2) made of implants (preferably N-well material) in a print head chip 110, inkjet print heads 120 (Figure 3) including these TSRs 10, and inkjet printers 130 (Figure 4) including these print heads 120.

Figure 1 shows a prior art print head chip 220 including an ink via 24 surrounded by a meandering metal TSR 20.

With the introduction of CMOS logic, N-Well material was added for the ability to create PMOS transistors in the CMOS logic blocks. N-Well is one of the most resistive materials on Lexmark CMOS print head chips and has a larger temperature coefficient than AlCu (see Table 1 below). Other implants listed are: NSD (n-type implant used for NMOS transistor source and drain areas), LDD (n-type implant used to form the lightly doped drain side of an n-type transistor), and PSD (p-type implant used for PMOS transistor source and drain areas).

	$\alpha$ ( $\Omega$ / $^{\circ}$ C)	$R_s$ ( $\Omega$ / $\square$ )
N-Well	.0051	1200
NSD	.0022	36
LDD	.0030	2100
PSD	.0013	86
Aluminum-Copper	.0036	.05

**Table 1**

**Comparison of N-Well Diffusion and other implants and AlCu Temperature Coefficients and Resistivities**

Figure 2 shows an inkjet print head chip 110 of the present invention including

an ink via 24 surrounded by TSRs 10 made of implants (preferably N-well material) in print head chip 110.

By using N-Well for the TSR material, the following improvements over prior art metal TSR will result:

- 5 1.) N-Well has a higher temperature coefficient,  $\alpha$ . Therefore, temperature changes are easier to detect.
- 2.) N-Well has a higher resistance R. Therefore, more precise measurements can be made and temperature is even easier to detect because changes in resistance are so much bigger.
- 10 3.) Larger blocks of material can be used, which will provide a tighter tolerance on the resistance since there is less effect from line width process variations.
- 4.) The larger blocks of N-Well can overlap other metal traces with no functional effect, which can save silicon area.

While N-Well is the preferred implant for TSRs, many implants (such as NSD, LDD, and PSD) used in the geometry shown in Figure 2 will provide the same advantages over metal TSRs, and are included in the scope of the present invention.

The novel TSRs of the present invention can be used in various types of ink jet print heads, such as those shown in Lexmark's U.S. Patent No. 6,398,333 and 6,382,758 (both incorporated herein by reference).

20 The novel TSRs of the present invention can be produced in a print head chip by the following method: Ion implantation of donor or acceptor atoms, followed by a thermal diffusion cycle, or by any standard method for producing MOS print head chips known to those of ordinary skill in this art.

The print head chip 120 of the present invention will typically contain 1-1000  
 25 TSRs 10 of the present invention. Each of these TSRs (when made of N-well material) can be, for example, 6 - 1000  $\mu\text{m}$  wide by 6 - 100,000  $\mu\text{m}$  long by 1 - 2  $\mu\text{m}$  thick. Each of these TSRs (when made of NSD material) can be, for example, 2 - 1000  $\mu\text{m}$  wide by 2 - 100,000  $\mu\text{m}$  long by 0.4 - 0.8  $\mu\text{m}$  thick. Each of these TSRs (when made of LDD material) can be, for example 2 - 1000  $\mu\text{m}$  wide by 2 - 100,000  
 30  $\mu\text{m}$  long by 0.2 - 0.4  $\mu\text{m}$  thick. Each of these TSRs (when made of PSD material) can be, for example, 2 - 1000  $\mu\text{m}$  wide by 2 - 100,000  $\mu\text{m}$  long by 0.4 - 0.8  $\mu\text{m}$  thick.

Aside from the novel TSRs of the present invention, print head chip 110 can be the same as chip 10 of Lexmark's U.S. Patent Nos. 6,540,334; 6,398,346;

6,357,863; 5,984,455; 5,942,900.

Figure 3 shows an inkjet print head 120 of the present invention. Figure 4 shows an inkjet printer 130 including print head 120. Aside from the novel TSRs of the present invention, printer 130 can be the same as current Lexmark printers (such as Lexmark® Model Z51, Lexmark® Model Z31, and Lexmark® Model Z11).

The present invention includes an inkjet print head chip 110 having MOS logic blocks (CMOS, NMOS, or PMOS logic blocks), resistor elements to heat the chip, and a controller of the resistor elements and temperature sense resistors 10 implanted in the chip, the temperature sense resistors 10 being operatively connected to the controller of the resistor elements to enable the controller to monitor the chip temperature to control the resistor elements to heat the chip. For elements of the present invention not shown herein, see one or more of the U.S. Patents mentioned herein (e.g., Lexmark U.S. Patent No. 6,299,273), all of which are incorporated herein by reference.

#### 15 PARTS LIST:

The following is a list of parts and materials suitable for use in the present invention:

- 10 temperature sense resistors of a first embodiment of the present invention
- 20 prior art metal temperature sense resistor
- 20 24 ink via
- 110 inkjet print head chip of a first embodiment of the present invention
- 120 inkjet print head of the present invention
- 130 inkjet printer including print head 120
- 220 prior art inkjet print head chip

25 All measurements disclosed herein are at standard temperature and pressure, at sea level on Earth, unless indicated otherwise.

The foregoing embodiments are presented by way of example only; the scope of the present invention is to be limited only by the following claims.